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EVAPORATION MEMORANDUM NO.29.

DUPLICATE

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QUALITY-CONTROL OF MONTHLY TOTALS OF POTENTIAL EVAPOTRANSPIRATION (p.e.) OBTAINED FROM IRRIGATED LYSIMETERS.

1. Assumptions - Three assumptions are made. The first is that the Penman formula (with good-quality climatological data) gives a very close approximation to the rate of evaporation (evapotranspiration) from soil covered by short grass, the roots of which are never short of water; few will question this, and it is very strongly supported in recent work by Penman, French and Long (page 64) in which data from a neutron moisture meter are used to derive estimates of evaporation which are compared with calculated values. The second assumption is that a simple, irrigated lysimeter well exposed, in good condition and well managed gives values which compare very well indeed with good-quality Penman estimates made from climatological data obtained at the lysimeter sites, (Wales-Smith[2,3]). The third assumption is that Penman potential evaporation is a continuous variable in space and time and can be mapped. This third assumption is supported by the work of Grindley[4] and by comparisons between monthly totals of p.e. between adjacent stations (Wales-Smith [2,3]).

2. Method

2.1. Reference Fields. Reference fields of monthly p.e. for 1971 were constructed for Great Britain using estimates for about 110 stations.† The version of the Penman equation was that set out in Reference 4 and daily duration of bright sunshine was the measure of radiation. The guiding principles in constructing the analyses were (i) the dominance of the aerodynamic term in winter, (ii) that potential evaporation decreases with increasing height above sea level and (iii) to attempt to allow for the effects of airflow over high ground.

2.2. Comparisons

Monthly values of (Penman) p.e. were interpolated from the isopleth patterns, at each lysimeter station (Fig.1.) The lysimeter and Penman values are set out in Table 1.

Scatter diagrams were plotted as follows:-

(i) Penman vs lysimeter p.e. for each station

(ii) Penman and lysimeter p.e. (using two types of symbol) for pairs of stations. (X = Penman estimate , • = lysimeter total)

2.3. Adjustments

A 1:1 relationship was assumed for Penman and lysimeter values of monthly p.e. and the Penman values were assumed to be correct. The 1:1 line was drawn (on each single-station plot) and also lines 10% above and below the 1:1 line (for lysimeter values); Fig.2* is an example.

Each point was marked with an identifying month-label and where it fell

* all station plots shown in Appendix 2 (available on request)

† Appendix 1. (available on request).

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outside the ± 10% lines was taken up or down to contact with the lower or upper 10% line respectively. The Penman value of each point was retained. Discarded values for lysimeter p.e. were ringed and adjusted values were plotted as triangles. Fig.3.* is an example. Regression lines were drawn by eye, using Penman points (x).
2.4. Adjusted lysimeter values are compared with original values in Table 2.

3. Errors in lysimeter measurements of p.e.

3.1. Equation. The lysimeter equation is

$$E = R + I - P$$

where E = evaporation
R = rainfall
I = irrigation water
P = percolated water

If the lysimeter is in good condition, if temporarily impermeable layers do not develop in the soil block and if we neglect months with snowfall and frozen soil the daily observations, as processed by Green[5], should add up to a month's evaporation. Clearly, however, even if the apparatus is in perfect condition and well sites, R, I and P can be incorrectly measured and the rooting zone will not be kept at field capacity if irrigation is insufficient.

3.2. Apparatus and site shortcomings and other errors.

3.2.1. Leaks. If the apparatus leaks some percolate will fail to reach the collecting vessel and the evaporation will be over-estimated.

3.2.2. Site. If the lysimeter is more or less sheltered than the climatological station (if there is one) the p.e. values will differ. If there is no climat.station but the lysimeter is not in an area-representative site the lysimeter values may not agree with values interpolated from analyses.

3.2.3. Rainfall. If the rain measurement does not agree with the rain actually received by the lysimeter errors will occur as follows:

(i) More rain on lysimeter than measured from gauge:

Let measured rain = R and let rain on lysimeter = R + r

Calculated E = I + R-P

but true E = I + R +r - P

i.e. calculated E < true E

(ii) Less rain on lysimeter than measured from gauge:

Let measured rain = R + r and let "true" rain = R.

Calculated E = I + R + r - P

but true E = I + R - P

i.e. calculated E > true E.

* all plots included in Appendix 2 - (available on request)

3.2.4. Irrigation Water

(i) More irrigation applied than used in calculation:

Let actual irrigation = I + i and recorded irrigation = I

Calculated E = I + R - P

but true E = I + i + R - P

i.e. calculated E < true E.

(ii) Less irrigation applied than used in calculation:

Let actual irrigation = I and recorded irrigation = I + i

Calculated E = I + i + R - P

but true E = I + R - P

i.e. calculated E > true E.

3.2.5. Percolated water

P "over-measured"	E too small
P "under-measured"	E too large

3.2.6. Under-irrigation

Unless the rooting zone of the grass is kept at field capacity the lysimeter can not measure potential evaporation and values will always be low in relation to Penman estimates. Some observers do not visit their apparatus each day and it is almost certain that errors arise in this way, during dry weather.

4. Identification of likely errors.

Lysimeter measurement relative to Penman p.e.

Always high	Suspect a leak	L
Always low	Suspect extreme shelter	Sh
	" insufficient irrigation	F
High	Rainfall measurement higher*	Rm^+
	Irrigation " " *	Im^+
	Percolate " lower*	$\overline{Pm}$
Low	Rainfall measurement lower*	$\overline{Rm}$
	Irrigation " " *	$\overline{Im}$
	Percolate " higher*	Pm^+

* than actually reaching lysimeter or collecting vessel

The symbols on the right-hand side of the above relationship/ fault table are a convenient shorthand for tabulating comments those for 1971 are given in Table 3.* It is suggested that lysimeter totals within 10% of adjusted totals (2.3.) should be accepted for archives etc.

1. French, B.K. Long, I.F. and Penman, H.L.

Water use by farm crops III. Report of Rothamsted Experimental Station for 1972, Part 2.

2. Wales-Smith, B.G.

Comparisons of estimates and measurements of monthly totals of potential evaporation/transpiration. Evaporation Memo No.18 (unpublished) Meteorological Office Library.

3. Wales-Smith, B.G.

An attempt to estimate the reliability of records of monthly totals of daily measurements of evapotranspiration obtained from a network of irrigated, non-weighing lysimeters. Evaporation Memo No.19 (unpublished) Meteorological Office Library.

4. Grindley, J.

Estimation and mapping of evaporation IASH Proc.Reading Symp. July 1970. World Water Balance.

5. Green, F.H.W.

A technique for measuring potential evaporation and some of its applications. Water and Water Engineering Dec.1960.

Bracknell
December 1973.

* It must be remembered, however, that a station could have more than one fault and that these faults may <u>not</u> act in the same sense.

TABLE 1.

POTENTIAL EVAPOTRANSPIRATION (MM) 1971 { L = LYSIMETER, P = PENMAN FORMULA

	ACHNAGAICHAN		ALICE HOLT		CAWOOD		CRAWFORDJOHN		CULDROSE		CWM DYLI	
	L	P	L	P	L	P	L	P	L	P	L	P
JAN	4	10	4	2	5	3	1	1	20	14		11
FEB	21	4	6	11	8	10	3	3	28	14		9
MAR	34	17	21	32	22	23	21	18	37	29	40	25
APR	43	34	35	55	39	47	42	47	57	50	61	50
MAY	70	74	45	91	68	86	66	75	106	83	52	85
JUN	62	54	64	84	73	81	68	73	106	79	48	77
JUL	74	88	81	109	98	97	89	85	142	117	64	98
AUG		44	51	83	66	67	41	53	98	75	40	64
SEP		35	48	50	58	48	37	33	108	59	35	43
OCT		17	21	22	33	26	28	11	78	32	30	20
NOV	26	7	9	3	21	11	8	2	62	14	21	7
DEC	27	9	4	4	1	5	6	3	43	10	13	9
APR SEP		329	324	472	402	426	364	366	617	463	300	417
YEAR		393	389	546	492	504	431	404	885	576		498

	EAST DEREHAM		EDGBASTON		GRENDON UNDERWOOD		HAPPENDON		HARRIS		INVERPOLLY	
	L	P	L	P	L	P	L	P	L	P	L	P
JAN	4	2	9	2	9	2	2	1	12	17	13	28
FEB	13	14	15	13	14	13	5	3	22	17	15	22
MAR	22	30	29	27	31	29	16	20	27	32	22	28
APR	36	48	45	51	97	54	54	48	29	50	34	48
MAY	79	81	66	87	77	86	82	77	40	75	40	78
JUN	71	82	50	80	68	78	72	75	46	87	34	69
JUL	110	102	72	104	107	105	90	87	49	70	41	72
AUG	53	73	59	68	82	76	47	54	57	59	45	58
SEP	63	53	45	45	51	46	45	33	40	42	40	53
OCT	27	35	23	20	41	22	8	11		20		24
NOV	9	5	14	5	5	3	2	2		15		18
DEC	2	4	8	8	4	4	0	3		15		16
APR SEP	412	439	337	435	482	445	390	374	261	383	234	378
YEAR	489	529	435	510	586	518	423	414		499		514

	Killiechonate		Kinlochewe		Lossiemouth		Moor House		Overton Down		Prabost	
	L	P	L	P	L	P	L	P	L	P	L	P
Jan	6	12	4	24	19	7	17	1		3	0	5
Feb	9	7	3	19	24	22	17	8	15	10	0	14
Mar	18	21	14	25	26	32	19	18	22	24	11	30
Apr	24	34	42	40	59	55	36	38	45	51	34	52
May	34	71	61	71	92	90	74	66	120	86	60	78
Jun	44	69	53	70	82	74	68	65	114	84	64	87
Jul	64	72	41	72	98	92	66	69	73	118	48	73
Aug	62	46	42	50	88	67	36	50	47	67	40	62
Sep	86	33	46	38	41	47	34	32	60	51	24	48
Oct		10		16	9	30	26	12	57	17	6	19
Nov		8		12	4	15	20	0	39	3	2	17
Dec		11	28	14	2	23	14	0	21	4	1	15
Apr-Sep	264	325	285	341	460	425	314	320	459	457	270	400
Year		394		451	544	554	427	359		518	290	510

	Stenness		Strachan		Sutton Bonington		Tregaron-ty-coed		Westlands Farm		Whitehillocks	
	L	P	L	P	L	P	L	P	L	P	L	P
Jan	15	7		6	7	2	0	9	0	1		7
Fer	22	13	2	8	11	11	3	8	6	16	3	5
Mar	39	26	5	28	23	28	10	22	22	31	13	25
Apr	49	45	37	44	56	45	35	42	32	46	39	41
May	71	75	54	80	83	80	61	76	57	79	60	78
Jun	74	70	56	61	69	75	79	70	55	77	57	60
Jul	87	75	98	87	104	99	64	84	92	93	68	83
Aug	62	56	70	63	75	71	38	48	52	70	51	57
Sep	46	40	48	39	59	44	31	37	56	53	52	36
Oct	28	22	28	18	35	19	21	16	28	32	32	13
Nov	27	17	16	4	16	5	8	5	3	11	18	3
Dec	23	16	6	10	12	4	2	4	0	5	10	9
Apr Sep	389	361	363	374	446	414	308	357	344	418	327	355
Year	543	462		448	550	483	352	421	403	514		417

	Wye Down		Yarner Wood		Yeovilton	
	L	P	L	P	L	P
Jan	8	5	0	4	7	8
Feb	19	10	2	6	21	12
Mar	29	28	14	22	40	35
Apr	46	44	35	45	82	57
May	72	78	54	82	110	86
Jun	73	83	59	78	94	86
Jul	110	98	92	108	166	117
Aug	80	80	70	60	110	80
Sep	70	47	53	47	97	51
Oct	38	14	24	18	60	26
Nov	13	5	12	1	19	7
Dec	5	4	3	5	10	12
Apr Sep	451	430	363	420	659	477
Year	563	496	418	476	816	577

TABLE 2. Monthly totals of daily lysimeter measurements of potential evapotranspiration (left-hand columns) and adjusted totals (right-hand columns).

(Values in mm.)

Month	Achnagoricham		Alice Holt L.		Cawood		Crawfordjohn		Culdrose		Cwm Dyli	
Jan	4	8	4	3	5	3	1		20	16		
Feb	21	4	6	10	8		3		28	16		
Mar	34	19	21	28	22		21	20	37	32	40	28
Apr	43	37	35	49	39	41	42		57	56	61	56
May	70		45	81	68	77	66		106	92	52	76
Jun	62	59	64	75	73		68		106	88	48	69
Jul	74	79	81	98	98		89		142	129	64	88
Aug			51	74	66		41	47	98	83	40	57
Sep			48		58	53	37	36	108	66	35	38
Oct			21		33	29	28	12	78	36	30	22
Nov	26	8	9	4	21	12	8	3	62	16	21	8
Dec	27	9	4		1	4	6	3	43	11	13	10

	East Dereham		Edgbaston		Grendon Underwood		Happendon		Harris		Invernelly	
Jan	4	2	9	1	9	1	2		12	15	13	25
Feb	13		15		14		5	4	22	19	15	19
Mar	22	26	29		31		16	18	27	29	22	25
Apr	36	42	45		97	59	54		29	45	34	43
May	79		66	78	77		82		40	78	40	70
Jun	71	73	50	71	68	70	72		46	63	34	62
Jul	110		72	93	107		90		49		41	64
Aug	53	65	59	61	82		47	48	57		45	52
Sep	63	58	45		51		45	37	40		40	47
Oct	27	31	23		41	23	8	10				
Nov	9	5	14	5	5	3	2					
Dec	2	3	8		4		0					

TABLE. 3. CODED COMMENTS ON MONTHLY LYSIMETER TOTALS
(MARCH - OCTOBER) √ = ACCEPTABLE, ⟷ = ALL MONTHS THE SAME.

	M	A	M	J	J	A	S	O
Achnagairchan			√	√	√			
Alice Holt Lodge								
Cawood								
Crawford John								
Culdrose								
Cwm Dyli								
East Dereham								
Edgbaston								
Grendon Underwood								
Happendon								
Harris								
Inverpolly								
Killiechonate								
Kinlochewe								
Lossiemouth								
Moor House								
Overton Down								
Rhabost								
Stemness								
Strachan								
Sutton Bonington								
Tregaron ty-coed								
West Heads Farm								
White Hillocks.								
Wye Down								
Yarner Wood								
Yeovilton								

Month	Killiechonate		Kinlochewe		Lossiemouth		Moon House		Overton Down		Prabost.	
Jan	6	11	4	21	19	7	17	1			0	13
Feb	9	8	3	17	24		17	9	15	11	0	12
Mar	18	19	14	22	26	28	19		22		11	26
Apr	24	30	42		59		36		45		34	46
May	34	63	61	63	92		74	72	120	95	60	70
Jun	44	61	53	62	82		68		114	93	64	78
Jul	64		41	64	98		66		73	105	48	65
Aug	62	51	42	44	88	74	36	44	47	59	40	55
Sep	36		46	41	41	42	34		60	57	24	43
Oct					9	26	26	13	57	19	6	17
Nov					4	13	20	0	39	3	2	15
Dec			28	15	2	20	14	0	21	4	1	13

	Stenness		Strachan		Sutton Bonnington		Tregaron-ty-Coed		Westlands Farm		Whitehillocks.	
Jan	15	8			7	3	0	8	0			
Feb	22	14	2	7	11		3	7	6	14	3	4
Mar	39	29	5	25	23	25	10	19	22	27	13	22
Apr	49		37	39	56	50	35	37	32	41	39	
May	71		54	71	83		61	68	57	71	60	70
Jun	74		56		69		79	77	55	69	57	
Jul	87	83	98	96	104		64	75	92		68	74
Aug	62		70		75		38	43	52	62	51	
Sep	46	44	48	43	59	49	31	33	56		52	40
Oct	28	24	28	20	35	22	21	18	28		32	15
Nov	27	19	16	5	16	7	8	5	3	10	18	4
Dec	23	18	6	9	12	5	2	3	0	4	10	
						9						

	4yeDown		yarnerWd.		Yeavilton								
Jan	8	5	0	3	7								
Feb	19	12	2	5	21	14							
Mar	29		14	19	40								
Apr	46		35	40	82	63							
May	72		54	73	110	95							
Jun	73	74	59	70	94								
Jul	110	108	92	97	166	130							
Aug	80		70	66	110	88							
Sep	70	52	53	52	97	57							
Oct	38	16	24	20	60	30							
Nov	13	6	12	2	19	9							
Dec	5		3	4	10								

Fig.1.
Lysimeter Stations.
200 100 50 0 100 200 400 600 metres
Orkneys and Shetlands
Inverpolly
Kinlochewe
Lossiemouth
Tirbost
Tichnagaichan
Harris
Killiechonate
Strachan
Whitehillocks
Happendon
Crawfordjohn
Moor House
Stenness
Cawood
Westlands Farm
Cwm Dyli
Slatter
Bonington
East Dereham
Edgbaston
Tregaron
Ty-Coed
Grendon Underwood
Overton Down
Wye Down
Alice Holt Lodge
Yeovilton
Turner Wood
Culdrose
IRISH GRID
NATIONAL GRID
KILOMETRES
0 20 40 60 80 100
0 10 20 30 40 50 60
STATUTE MILES
Channel Islands
U.T.M. GRID
ZONE 30U
Met.O.(Carto.)D.O.)1297A

Fig 2

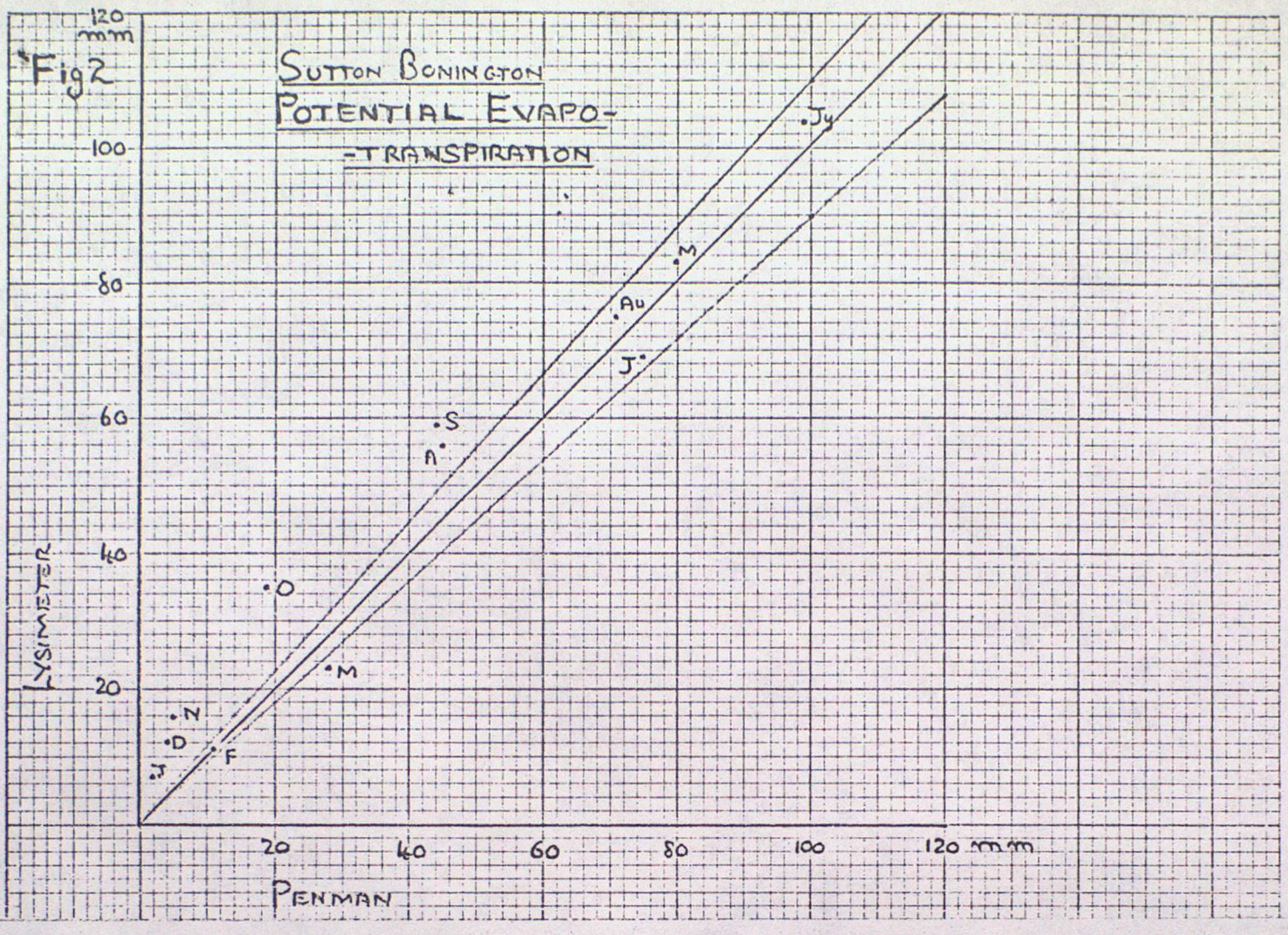
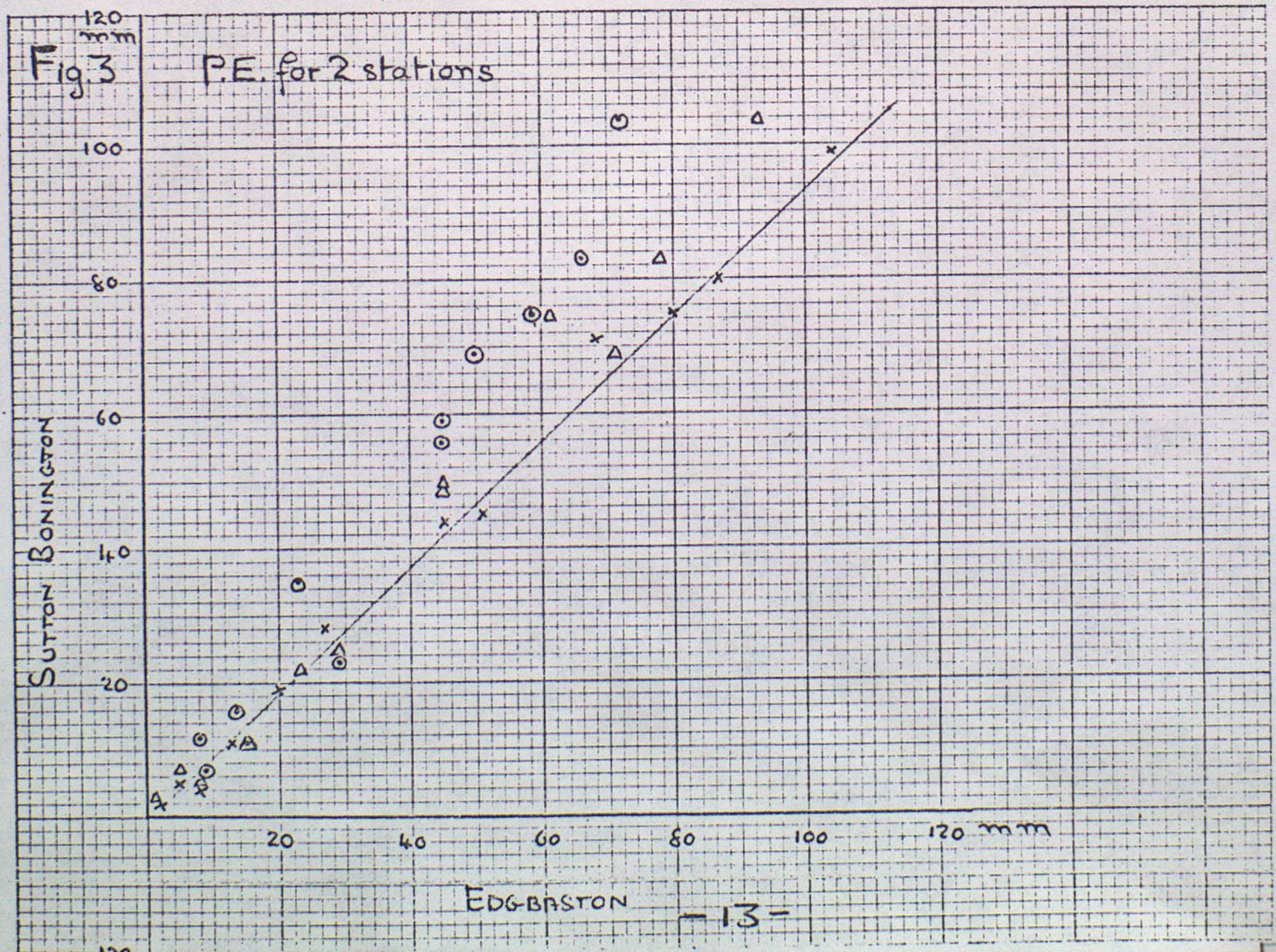

SUTTON BONINGTON
POTENTIAL EVAPO-
-TRANSPIRATION
LYSIMETER
PENMAN
mm
120
100
80
60
40
20
J
F
M
A
M
J
Jy
Au
S
O
N
D
J
20
40
60
80
100
120 mm

Fig 3


P.E. for 2 stations
SUTTON BONINGTON
EDGBASTON
mm
120
100
80
60
40
20
20
40
60
80
100
120 mm